AN INTERNATIONAL COOPERATION TO IMPROVE DELAYED NEUTRON DATA

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Delayed neutron data uncertainties may result in undesirable conservatism in the design and operation of nuclear reactor control systems. Interest in improving the accuracy of delayed neutron data began to grow in the late 1980s and early 1990s when some discrepancies between experimental results and calculational results were noted from available in-pile measurements. As a result, an international working group was formed under the auspices of the Nuclear Energy Agency's (NEA) Working Party on International Evaluation Cooperation (WPEC), Subgroup 6 (SG6), to review, improve and validate delayed neutron (DN) data.

Under the guidance of Dr. Alexandre Filip (CEA Cadarache, France), who for many years was coordinator of the SG6, the SG6 has reviewed delayed neutron data at three different levels:

- individual precursor, or microscopic, level,
- aggregate precursors, or macroscopic, level, and
- in-pile integral measurement level.

The objective of the first level was to evaluate precursor fission yields, half-lives, and DN emission probabilities (P_n values) for each individual precursor. These data are used to simulate the aggregate behavior of delayed neutrons, from which the total delayed neutron yields and group parameters are estimated using the summation technique. Good agreement between the summation results and the experimentally-observed aggregate behavior of delayed neutrons is a direct indication that our data base for cumulative fission yields and DN emission probabilities has evolved to the point where we have true predictive capabilities concerning delayed neutrons.

The objective of the second level was to perform measurements and evaluations of the aggregate behavior of delayed neutron emissions from pure fissile isotope targets. From these data, we obtain total DN yields and group constants that characterize the time-dependent behavior of delayed neutrons for numerous fissioning isotopes over a wide variety of incident neutron spectra.

The objective of the third level was to determine whether or not our database was sufficiently accurate enough to predict the measured effective delayed neutron fraction, $ß_{eff}$, and reactivity scale for a wide variety of critical assemblies.

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Since April 1990, when the SG6 started its activities under the coordination of Professor Gosta Rudstam of Uppsala University (Studsvik, Sweden), important work has been carried out at all three levels at numerous laboratories through out the world. In particular, the SG6 committee has been involved in promoting and monitoring microscopic delayed neutron work at Uppsala (Sweden), Birmingham (U.K.), Mainz (Germany), Tokyo Waseda, Nagoya University (Japan), Los Alamos National Laboratory (U.S.A), Obninsk (Russia), Grenoble and Cadarache (France), Winfrith (U.K.), University of Massachusetts Lowell, and the Idaho National Engineering Laboratory (U.S.A). At the macroscopic level, the SG6 committee has promoted and monitored macroscopic measurements at the Birmingham University (U.K.), at the Frank Laboratory in Dubna (Russia), and at the Obninsk Institute of Physics and Power Engineering (Russia). The SG6 has also monitored experimental work at the Texas A&M University, and at the Los Alamos National Laboratory (U.S.A). Concerning activities at the integral measurement level, the SG6 underlined the need for benchmark experimental data for the delayed neutron fraction and the reactivity scale in operating systems. As a result, the SG6 committee promoted and defined two international benchmark experiments designed to measure $ß_{eff}$ using different techniques on cores containing various mixtures of uranium and plutonium. These experiments were performed at two, fast-critical facilities - the Masurca facility at Cadarache (France) and the Fast-Critical Assembly (FCA) operated by the Japan Atomic Energy Research Institute (JAERI) located in Tokai-Mura (Japan). Moreover, the SG6 has promoted and monitored the analyses of the experimental data at the Los Alamos National Laboratory (U.S.A.), Oak Ridge National Laboratory (U.S.A), JAERI and Hitachi R&D Division (Japan), and at SKODA (Czech Republic).

Following the retirement of the last SG6 coordinator, Dr. Alexandre Filip, in early 1996, I was entrusted with the SG6 coordination. In order to review the progress of the activities performed at the three different levels, a meeting entitled "Colloquy on Delayed Neutron Data" was held at IPPE Obninsk, 9-10th April 1997. At this meeting, it was concluded that the SG6 committee would soon realize its major goals of

- obtaining state-of-the-art delayed neutron data for a wide variety of isotopes;
- recommending a new set of DN yields for the major fissile isotopes; and
- developing a new few-group model that would be more convenient for reactor applications, and would have a better physical basis than the presently used six-group model.

The SG6 work was officially terminated at the end of 1999. Last year, Progress *in Nuclear Energy* hosted a special issue of its journal to present the results of the International Benchmark Experiment of the Effective Delayed Neutron Fraction in the Fast Critical Facility, FCA, JAERI, (PNE, Vol. 35, Number 2, 1999). In this second special issue, *Progress in Nuclear Energy* has graciously allowed the SG6 committee the opportunity to present other results obtained by the committee. In particular, in this issue, we present a paper that recommends a new set of DN yields for the major fissile isotopes, a paper that recommends a new 8-group model based on a consistent set of half-lives for all isotopes and all incident neutron energies, and a new set of delayed neutron spectra for the 8-group model. Moreover, this special issue also includes other noteworthy DN research being performed by scientists who were not SG6 committee members. It is our intentions that this special issue will help educate other scientist as to our current understanding of delayed neutron data and its application to reactor physics.

Despite the termination of the SG6 committee's work, interest in DN data is far from being terminated. Interest in delayed neutrons is now mainly focused on minor actinides and thorium isotopes for the new trends in reactor technology. In particular, delayed neutron data is needed for use with reactor systems based on exotic fuel recycling strategies such as high burn-up fuel systems, actinide burners, plutonium stock burners, etc. There are many questions that need to be addressed before these new concepts can be fully realized, such as the dependence of the DN yield and group parameters of minor actinides on the incident neutron energy below 4 MeV. Because of its importance on the reactivity scale, it is anticipated that the group parameters might need to be made an explicit function of the incident neutron energy in order to increase the predictive capabilities for these systems. Following the “Colloquy on Delayed Neutron Data” meeting, it was indicated at that time that a new committee would be formed in the near future to continue research on the incident-neutron energy dependence of both the DN yields and group parameters of isotopes used in these future reactor systems.

I would like to take this opportunity to thank many of the individuals who made it possible for the SG6 committee to perform this valuable work. In particular, I would like to thank Dr. Massimo Salvatores (CEA, France) and Dr. Richard D. McKnight (Argonne, USA), who were among the Subgroup initiators. Since the formation of the SG6 committee, these two gentlemen have actively contributed to the subgroup, the first one as president of the WPEC for many years, and the second one as monitor-scientist of the SG6 activities. Many thanks to Dr. John Rowlands (consultant to the OECD NEA) for his important technical contributions to the committee. I would also like to thank Dr. Claes Nordborg, the NEA/WPEC technical secretary, who actively and patiently helped the subgroup function most efficiently. I would also like to thank Philip Fink, who was the president of the WPEC during these last few years. Special thanks are due to the first two SG6 coordinators, Professor Gosta Rudstam and Dr. Alexandre Filip. Last, but not least, I would like to express my heartfelt gratitude to all the following SG6 members for their excellent contributions to the work of this unique international committee: Dr. J. Campbell (Los Alamos National Laboratory, U.S.A), Dr. T. R. England (Los Alamos National Laboratory, U.S.A), Dr. E. Fort (CEA Cadarache, France), Dr. W. I. Furman (Frank Laboratory of Neutron Physics at Dubna, Russia), Dr. R. Jacqmin (CEA Cadarache, France), Dr. J. Katakura (Japan Atomic Energy Research Institute, Japan), Dr. R. W. Mills (BNFL at Sellafield, U.K.), Dr. M. Martini (ENEA c/o CEA Cadarache, France), Dr. S. Okajima (Japan Atomic Energy Research Institute, Japan), Dr. K. Oyamatsu (Aichi-Shukutoku University, Japan), Professor T.A. Parish (Texas A&M University, U.S.A.), Dr. V.M. Piksaikin (Institute of Physics & Power Engineering at Obninsk, Russia), Dr. G. D. Spriggs (Los Alamos National Laboratory, U.S.A), Dr. F. Storrer (CEA Cadarache, France), Dr. J. Svarny, (SKODA Co. Ltd., Czech Republic), Professor D. Weaver (University of Birmingham, U.K.), and Dr. W. B. Wilson (Los Alamos National Laboratory, U.S.A).